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Parkius karenwishnerae, a new genus and species of calanoid copepod (Parkiidae, new family) from benthopelagic waters of the eastern tropical Pacific Ocean

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Abstract.—The last five copepodid stages of a new genus and species of calanoid copepod, *Parkius karenwishnerae,* are described. The basis of the maxilliped of *P. karenwishnerae* is elongate distal to its two medial setae and its medial row of denticles; endopodal segments 2–5 are attenuate, forming a hook-like structure distally, with denticles along the concave margin. These character states are expected to be found in adult females of other species of *Parkius.* Parkiidae, new family, are clausocalanoidean copepods whose adult female has two Bradford's setae on the fifth enditic lobe on the basis of maxilla 2, two medial setae on the basis of the maxilliped, and endopodal segments of the maxilliped with 4, 0, 1, 1, 1 setae. On leg 1 the anterior denticles of Von Vaupel Klein's organ are found proximal to the presumptive boundary of the second endopodal segment.

Species in four families of calanoid copepods (Diaixidae Sars, 1902, Phaennidae Sars, 1902, Scolecitrichidae Giesbrecht, 1892, Tharybidae Sars, 1902) possess Bradford's setae on the terminal part of maxilla 2 and the syncoxa of the maxilliped. These setae are weakly-sclerotized and usually are without setules or with setules clustered at the tip to form a brush-like structure; they often are considered sensory in function and were named by Ferrari & Steinberg (1993) to recognize the contribution of Dr. Janet Bradford to the systematics of these families. The four families are presumed to constitute a monophyletic group within the calanoid copepod superfamily Clausocalanoidea (see Fleminger 1957); we refer to them here as bradfordian families. Presently there are 283 nominal species among 31 genera in these families (Table 1). Because most of the species are found below the epipelagic waters of all oceans, the expectation that new genera will be discovered as deeper pelagic and benthopelagic waters are sampled more thoroughly is fulfilled here with a description of a new species of calanoid copepod with similarly modified setae but with a distinctively modified maxilliped. A new genus and new a new bradfordian family are proposed for this copepod. Because the morphology of maxilla 1, maxilla 2, maxilliped, and endopod of leg 1 is considered important in establishing relationships among bradfordian families, these appendages are redescribed for *Diaixis hibernica* (Scott, 1896) and *Tharybis macrophthalma* Sars, 1902, which are the type species of the type genera of the Diaixidae and Tharybidae respectively.

Methods

Copepods were collected in the eastern tropical Pacific Ocean at Volcano 7 with a multiple sampling opening-closing net system with mouth opening of 40 cm by 40

Table 1.—Genera and number of species in five bradfordian families.

	No. species
Diaixidae Sars, 1902	
Anawekia Othman & Greenwood, 1994	1
Diaixis Sars, 1902	9
Parkiidae new family	
Parkius new genus	1
Phaennidae Sars, 1902	
Brachycalanus Farran, 1905	4
Cephalophanes Sars, 1907	3
Cornucalanus Wolfenden, 1905	8
Onchocalanus Sars, 1905	8
Phaenna Claus, 1863	2
Xantharus Andronov, 1981	1
Xanthocalanus Giesbrecht, 1892	53
Scolecitrichidae Giesbrecht, 1892	
Amallothrix Sars, 1925	46
Archescolecithrix Vyshkvartzeva, 1989	1
Heteramalla Sars, 1907	1
Landrumius Park, 1983	2
Lophothrix Giesbrecht, 1895	9
Macandrewella Scott, 1909	8
Mixtocalanus Brodsky, 1950	1
Parascaphocalanus Brodsky, 1955	1
Pseudophaenna Sars, 1902	1
Puchinia Vyshkvartzeva, 1989	1
Racovitzanus Giesbrecht, 1902	6
Scaphocalanus Sars, 1900	37
Scolecithricella Sars, 1902	26
Scolecithrix Brady, 1883	4
Scolecocalanus Farran, 1936	3
Scopalatum Roe, 1975	6
Scottocalanus Sars, 1905	13
Undinothrix Tanaka, 1961	1
Tharybidae Sars, 1902	
Neoscolecithrix Canu, 1896	4
Parundinella Fleminger, 1957	4
Tharybis Sars, 1902	9
Undinella Sars, 1900	10

cm and net mesh of 183 microns (Wishner & Meise-Munns 1984). During three dives (2146–2148) of the submersible ALVIN, horizontal tows were taken for one hr each, 1–5 m above the bottom at the base of Volcano 7 (13°23′N, 102°27′W) at depths of 2945–3010 m; samples were fixed at depth with gluteraldehyde (Wishner et al. 1995). Specimens were preserved later in the laboratory in 0.5% propylene phenoxytol/4.5% propylene glycol/95.0% water. They were cleared in steps through 50.0% lactic acid/50.0% water to 100% lactic acid and examined with differential interference optics, or stained by adding a solution of chlorazol black E dissolved in 70.0% ethanol/30.0% water and examined with bright-field optics.

The second through sixth copepodid stages are designated CII to CVI; CVI is the adult. Prosome and urosome are Pr and Ur respectively. Thoracic and abdominal somites are numbered according to their appearence during development as interpreted from data of Hulsemann (1991). The first and oldest thoracic somite bears the maxilliped and is fused with the cephalon. The youngest is the seventh; among calanoids it is the only thoracic somite without an appendage. In adult calanoids the seventh is the first somite of the urosome, and in adult females it is fused to the second abdominal somite to form the genital complex. The first and oldest abdominal somite is the most posterior; it bears the caudal rami. The youngest is immediately anterior to the oldest, and the remaining abdominal somites anteriorly increase in age and decrease in numerical designation.

Cephalic appendages are abbreviated A1 = antennule; A2 = antenna; Mn = mandible; Mx1 = maxillule; Mx2 = maxilla. Appendages on thoracic somites are Mxp = maxilliped (thoracopod 1); P1–5 = swimming legs (thoracopods 2–6). The caudal ramus is CR. Designations of appendage segments follow Huys & Boxshall (1991) except for Mx2 and Mxp; exopod = Re; endopod = Ri; medial lobe of a segment = li, lateral lobe = le. Ramal segments of Mx2 are exopodal and the Mxp has at most five endopodal segments (Ferrari 1995).

Ramal segments on thoracopods Mxp and P1–5 are numbered by their appearence during development (Hulsemann 1991, Ferrari & Ambler 1992, Ferrari 1995) and not proximal-to-distal as is the usual case in copepod descriptions. On the Mxp (Figs. 3F, 5D, 8C, J) the distal segment is the first endopodal segment, and the second endopodal segment is immediately proximal to the first. The third endopodal segment is immediately distal to the basis. The fourth endopodal segment is immediately distal to the third. The fifth endopodal segment is the middle segment. The second and first segments of a Mxp with a 5-segmented endopod are more distal and the third and fourth segments are more proximal. The distal segment of a ramus of P1–4 (Figs. 4E, F, 6F, 8E) is the first segment. The second segment is immediately distal to the basis. If present, the third segment is immediately proximal to the distal (or first) segment. For a 3-segmented ramus, the proximal segment is the second segment, the middle segment is the third segment, and the distal segment is the first segment. In the text, the number of setae recorded for ramal segments follows these schemes.

Armament elements of appendages here are termed setae regardless of their position or degree of rigidity. Examples of the position and morphology of setae are shown in the illustrations. Two setae and one aesthetasc on a segment of A1 are designated 2 + 1. Setules are epicuticular extensions of a seta; denticles are epicuticular extensions of an appendage segment; spinules are epicuticular extensions of a somite. Von Vaupel Klein's organ (Ferrari & Steinberg 1993, Ferrari 1995) on P1 (the appendage of thoracic somite 2) consists of the curved basal seta, and sensilla, denticles, or pores on the anterior face of the endopod.

Parkiidae, new family

Diagnosis.—Calanoid copepods with adult females having 3 inner setae on the first exopodal segment on leg 1 and a 1-segmented endopod, and 4 inner setae on the first exopodal segment and a 2-segmented endopod on leg 2. Maxilla 2 with 2 Bradford's setae on the fifth enditic lobe on the basis; with 3 thick, unarmed Bradford's setae and 5 with apical setules on the sixth enditic lobe plus exopod. Maxilliped with 3 Bradford's setae, 2 unarmed and 1 with apical setules, on the syncoxa; with 2 medial setae on its basis; with 4, 0, 1, 1, 1 setae on the endopod. Von Vaupel Klein's organ on leg 1 includes a well-defined group of long, thin denticles on the proximal third of the anterior face of the endopod; these denticles insert in an area proximal to the presumptive boundary of the second segment. Four derived character states of adult females exhaustive for the family are (1) maxilla 2 with 2 Bradford's setae on the fifth enditic lobe on the basis; (2) maxilliped with 2 medial setae on the basis; (3) endopodal segments of the maxilliped with 4, 0, 1, 1, 1 setae; and (4) leg 1 endopod with area of denticles of Von Vaupel Klein's organ in proximal position.

Parkius, new genus

Diagnosis.—Adult parkiid females (1) maxilliped with basis elongate distal to its two medial setae and medial denticle row; (2) with endopodal segments 2–5 attenuate, forming a hook-like structure distally, with denticles along the concave margin.

Type species.—*Parkius karenwishnerae*, by monotypy.

Etymology.—The genus honors Dr. Taisoo Park for his contributions to the phylogeny and taxonomy of calanoid copepods.

Parkius karenwishnerae, new species
Figs. 1–8

Material examined.—A dissected female holotype from dive 2148 at the Zoological Institute, St. Petersburg (ZISP 66823). Remaining copepods (CII—6 specimens; CIII—6 specimens; CIV—2 females and 4 males; CV—2 males; CVI—2 females) comprise one lot of paratypes in the National Museum of Natural History, Smithsonian Institution (USNM 278203). All specimens were collected at the base of Volcano 7 (13°23′N, 102°27′W), 1–5 m above the bottom, at depths of 2945–3010 m.

CVI female.—Length of 3 specimens 1.80 (holotype), 2.04, 2.15; average Pr length/Ur length = 3.6.

Pr (Fig. 1A): 5 segments; 1st a complex of 5 cephalic somites + Th1 and 2; Th3–6 simple and articulated; posterior margin of Th6 extended.

Ur (Fig. 1A–C): 4 segments; 1st a genital complex of Th7 and Abd2 (Fig. 1B, C) seminal receptacles curve dorsally and anteriorly; Abd3, 4, 1 articulated.

Rostrum (Fig. 1D): a simple plate with a pair of thin filaments; labrum and paragnath as illustrated.

A1 (Fig. 1E–G): 24 articulated segments with 3, 6 + 1, 2 + 1, 2, 2 + 1, 2, 2 + 1, 4 + 1, 1, 1, 2 + 1, 1, 2 + 1, 2, 2, 2, 2, 1 + 1, 1, 1, 2, 2, 2, 4 + 1 setae + aesthetascs.

A2 (Fig. 2A, B): coxa with 1 seta and a row of long denticles; basis with 2 setae. Re 6-segmented with 0, 1, 1, 1, 1, 4 setae. Ri 2-segmented with 1, 13 (6 terminal, 7 subterminal) setae.

Mn (Fig. 2C, D): coxa with 2 areas of denticles; basis with 3 setae. Re 5-segmented with 1, 1, 1, 1, 2 setae. Ri 2-segmented with 2, 9 setae.

Mx1 (Fig. 3A–C): le with 8 setae. Re 1-segmented with 8 setae and several denticles; baseoendopod with sets of 4, 2, 3, and 5 setae. Li 2, 3 both with 4 setae. Li 1 with 9 apical and 2 posterior setae; denticles on anterior surface.

Mx2 (Fig. 2E, F): li 1–4 of coxa each with 4, 3, 3, 3 setae each; li5 on basis with 4 setae, 2 are Bradford's setae without setules. Li6 + Re an indistinctly segmented complex with 8 Bradford's setae; terminal 3 setae thick without setules, 5 shorter with apical setules.

Mxp (Fig. 3D–F): syncoxa with denticles on disto-medial margin and 8 setae (1 short Bradford's with apical setules and 2 long Bradford's without apical setules). Basis elongate with medial row of denticles followed by 2 setae arising from an unsclerotized area; indistinct disto-medial lobe with 2 setae. Ri 5-segmented with 4, 0, 1, 1, 1 setae; intersegmental arthrodial membranes indistinct. Ri 2–5 attenuate, forming a hook-like structure with denticles along concave margin.

P1 (Fig. 4A, B): coxa with medial denticles; basis with medial seta and denticles. Re 3-segmented with 5 (3 medial, 1 terminal, 1 lateral), 1 (lateral), 2 (medial and lateral) setae; Re1 with lateral denticles and Re2 and 3 with medial denticles. Ri a 1-segmented complex with 5 setae (3 medial, 2 terminal). Von Vaupel Klein's organ with an area of long, thin denticles on proximal one-third of anterior face of Ri. A breaking plane on most inner setae of Ri; 2 breaking planes on most inner setae of Re.

P2 (Fig. 4C, D): coxa with medial seta and denticles. Basis unarmed. Re 3-segmented with 8 (4 medial, 1 terminal, 3 lateral), 2 (medial and lateral), 2 (medial and lateral) setae; posterior face of Re1 and 3 with distally polarized denticles. Ri 2-segmented with 5 (2 medial, 2 terminal, 1 lateral), 1 (medial) setae; posterior face of Ri1 with distally polarized denticles. A breaking plane on most inner setae of Ri; 2 breaking planes on most inner setae of Re.

P3 (Fig. 4E, F): coxa with medial seta and denticles. Basis unarmed Re 3-segmented with 8 (4 medial, 1 terminal, 3 lateral), 2 (medial and lateral), 2 (medial and lateral) setae; posterior face of Re1-3 with distally polarized denticles. Ri 3-segmented with 5 (2 medial, 2 terminal, 1 lateral), 1 (medial), 1 (medial) setae; posterior face of Ri1–3 with distally polarized denticles. A breaking plane on most inner setae of Ri; 2 breaking planes on most inner setae of Re.

P4 (Fig. 4G, H): coxa with medial seta, and medial and posterior denticles. Basis with posterior denticles. Re 3-segmented with 8 (4 medial, 1 terminal, 3 lateral), 2 (medial and lateral), 2 (medial and lateral) setae; posterior face of Re1–3 with distally polarized denticles. Ri 3-segmented with 5 (2 medial, 2 terminal, 1 lateral), 1 (medial), 1 (medial) setae; posterior face of Ri1–3 with distally polarized denticles. A breaking plane on most inner setae of Ri; 2 breaking planes on most inner setae of Re.

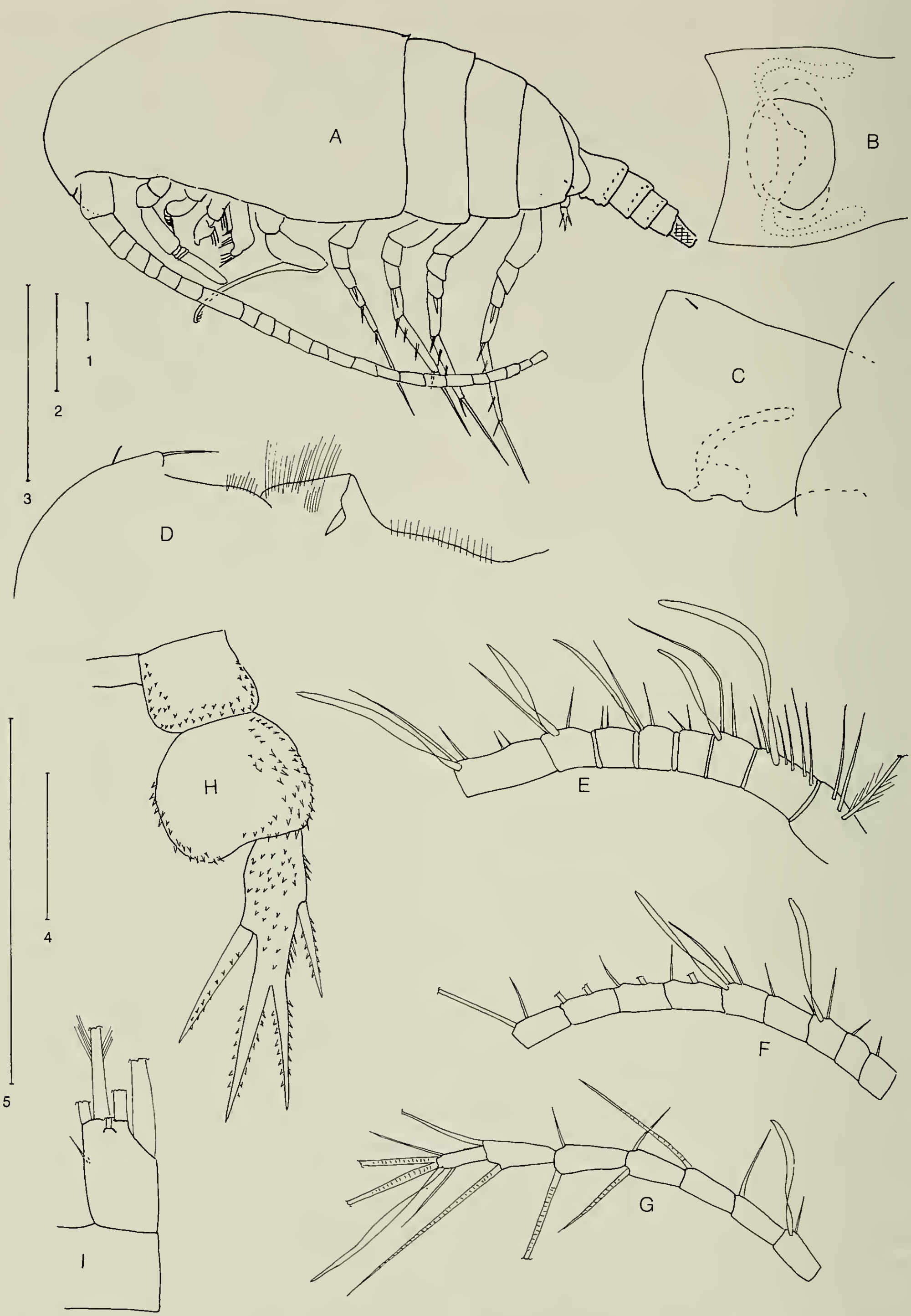

Fig. 1. *Parkius karenwishnerae,* new genus and species, CVI female: A, animal, left lateral (CR cross-hatched); B, genital complex, ventral; C, genital complex, right lateral; D, rostrum, labrum and labium, right lateral; E, A1 free segments 1–8; F, A1 free segments 9–17; G, A1 free segments 18–24; H, P5; I, CR. Wavy line cutoff indicates broken setae. Line 1 = 0.1 mm (A); line 2 = 0.1 mm (D, E, F, G); line 3 = 0.1 mm (I); line 4 = 0.1 mm (B, C); line 5 = 0.1 mm (H).

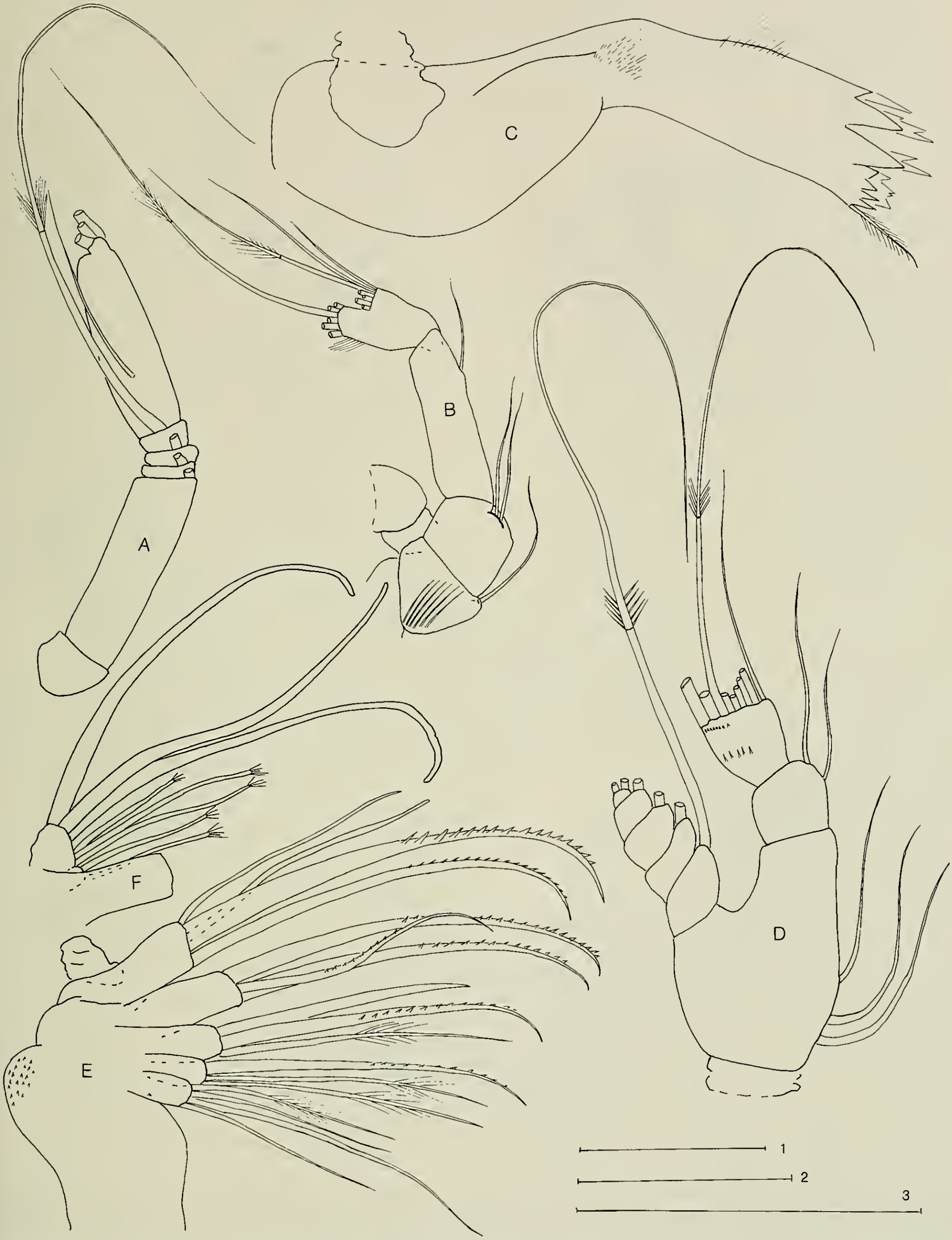

Fig. 2. *Parkius karenwishnerae,* new genus and species, CVI female: A, A2, Re; B, A2, coxa, basis and Ri; C, Mn, gnathobase, anterior; D, Mn, palp, anterior; E, Mx2, li 1–4 on coxa and li 5 on basis, posterior; F, Mx2, li 5 on basis (without setae) and li 6 + Re, posterior. Line 1 = 0.1 mm (A), B; line 2 = 0.1 mm (E), F; line 3 = 0.1 mm (C, D).

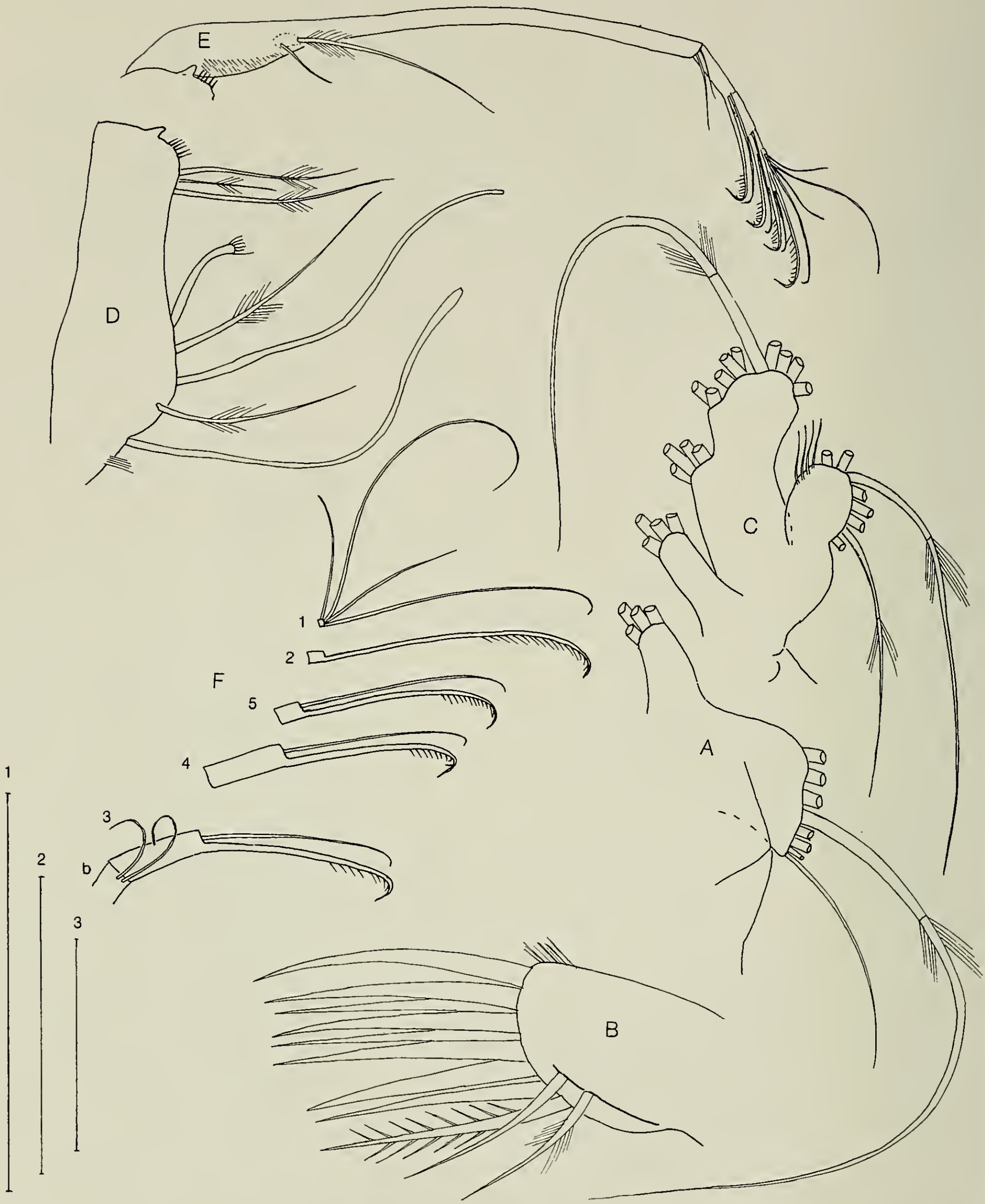

Fig. 3. *Parkius karenwishnerae,* new genus and species, CVI female: A, Mx1, syncoxa with li 1 detached, posterior; B, Mx1, li 1, posterior; C, Mx1, palp, posterior; D, Mxp, syncoxa; E, Mxp, basis and Ri; F, Mxp, detached segments of Ri (b = distal tip of basis; numbers to right indicate relative appearence of ramal segments during development). Line 1 = 0.1 mm (F); line 2 = 0.1 mm (A, B, C); line 3 = 0.1 mm (D, E).

P5 (Fig. 1H): coxa and basis without setae, with posterior denticles. Re 1-segmented with 2 setae (medial and lateral); apically with 2 attenuate points.

CR (Fig. 1I): 3 large, terminal setae, 1 large, postero-lateral seta, 1 small seta on a distomedial, ventral lobe, and 1 small seta on a dorsal lobe.

Fig. 4. *Parkius karenwishnerae,* new genus and species, CVI female: A, P1, coxa, basis and Ri, anterior (arrow indicates approximate position of presumptive boundary between Ri1 and Ri2, between proximal two medial setae); B, P1, Re, anterior; C, P2, coxa, basis and Ri, posterior; D, P2, Re, posterior; E, P3, coxa, basis and Ri, posterior (numbers to left indicate relative appearence of ramal segments during development); F, P3, Re (numbers to right indicate relative appearence of ramal segments during development), posterior; G, P4, coxa, basis and Ri, posterior; H, P4, Re, posterior. Wavy line cutoff indicates broken setae. Line 1 = 0.1 mm (A, B); line 2 = 0.1 mm (C–H).

CVI male.—Not found.

CV male.—Differs from CVI female as follows: length of 2 specimens 1.96, 2.11 mm; average Pr length/Ur length = 3.5.

Ur (Fig. 5A): 4 segments; Th7 and Abd 2, 3, 1 articulated.

A2 (Fig. 5B): Ri terminal segment with 12 setae (6 terminal, 6 subterminal).

Mn (Fig. 5C): Ri2 with 8 setae.

Mxp (Fig. 5D): Ri 4-segmented with 4, 0, 1, 1 setae.

P1: denticles on anterior face of Ri absent.

P5 (Fig. 5E): Re 2-segmented with 1 (medial), 1 (lateral) setae. Ri 1-segmented, apically attenuate.

CV female.—Not found.

CIV female.—Differs from CV male as follows: length of 2 specimens 1.37, 1.50 mm; average Pr length/Ur length = 3.7.

Pr (Fig. 5F): 6 segments; 1st a complex of 5 cephalic somites + Th1; Th2–6 articulated; posterior margin of Th6 extended.

Ur (Fig. 5F): 3 segments; Th7 and Abd2, 1 articulated.

A1 (Fig. 6A, B): 24 segments; proximal 8 segments with 3, 3 + 1, 1, 1, 1 + 1, 1, 1, 2 + 1 setae+aesthetascs.

Mn (Fig. 5G): Ri2 with 7 setae.

P1 (Fig. 6C): Re 2-segmented with 7 (4 medial, 1 terminal, 2 lateral), 1 (lateral) setae. Coxa without medial denticles.

P2 (Fig. 6D): Re 2-segmented with 9 (5 medial, 1 terminal, 3 lateral), 2 (medial and lateral) setae. Ri with fewer distally polarized denticles.

P3 (Fig. 6E): Re 2-segmented with 9 (5 medial, 1 terminal, 3 lateral), 2 (medial and lateral) setae. Ri 2-segmented with 6 (3 medial, 2 terminal, 1 lateral), 1 (medial) setae; posterior face of Ri2 without distally polarized denticles.

P4 (Fig. 6F): Re 2-segmented with 9 (5 medial, 1 terminal, 3 lateral), 1 (lateral) setae. Ri 2-segmented with 6 (3 medial, 2 terminal, 1 lateral), 1 (medial) setae.

P5 (Fig. 5H): Re 1-segmented with 1 (lateral) seta.

CIV male.—Differs from CIV female as follows: length of 4 specimens 1.47, 1.48, 1.53, 1.57 mm; average Pr length/Ur length = 3.9.

A1 (Fig. 6A, B): segments 14–16 on right appendage each with 2 setae.

P5 (Fig. 5I): Re 1-segmented with 1 (lateral) seta. Ri 1-segmented unarmed.

CIII.—Differs from CIV male as follows: length of 6 specimens 1.12, 1.14 (3 specimens), 1.16, 1.26; average Pr length/Ur length = 3.8.

Ur (Fig. 7A): 2 segments; Th7 and Abd1 articulated.

A1 (Fig. 7B–D): 23 articulated segments with 3, 1, 1, 1 + 1, 0, 1, 1 + 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1 + 1, 1, 1, 2, 2, 2, 4 + 1 setae + aesthetascs.

A2 (Fig. 8A): Ri terminal segment with 10 setae (5 terminal, 5 subterminal).

Mn (Fig. 8B): Ri2 with 6 apical setae.

Mx1 (Fig. 7E): Le with 7 setae. Re 1-segmented with 6 setae; baseoendopod with sets of 3, 3, and 5 setae. Li1 with 9 apical setae, 1 apical seta reduced in size.

Mxp (Fig. 8C): disto-medial lobe of basis with 1 seta. Ri 4-segmented with 4, 0, 0, 0 setae.

P2: Re denticles absent; sparse on Ri.

P3 (Fig. 8D): Re 2-segmented with 7 (4 medial, 1 terminal, 2 lateral), 1 (lateral) setae; posterior face of Re1 without distally polarized denticles; Re2 without denticles. Ri2 distally polarized denticles sparse.

P4 (Fig. 8E): coxa unarmed. Re 1-segmented with 7 (3 medial, 1 terminal, 3 lateral) setae. Ri 1-segmented with 6 (3 medial, 2 terminal, 1 lateral) setae.

P5 (Fig. 7F): a simple unarmed lobe on medial face of Th6.

CII.—Differs from CIII as follows: length of 6 specimens 0.91 (2 specimens), 0.93 (2 specimens), 0.95, 1.05 mm; average Pr length/Ur length = 3.5.

Pr (Fig. 8F): 5 segments; Th2–5 articulated; posterior edge of Th5 in shape of simple papilla.

Ur (Fig. 8F): 2 segments; Th6 with lateral lobes and Abd1 articulated.

A1 (Fig. 7G, H): 19 articulated segments

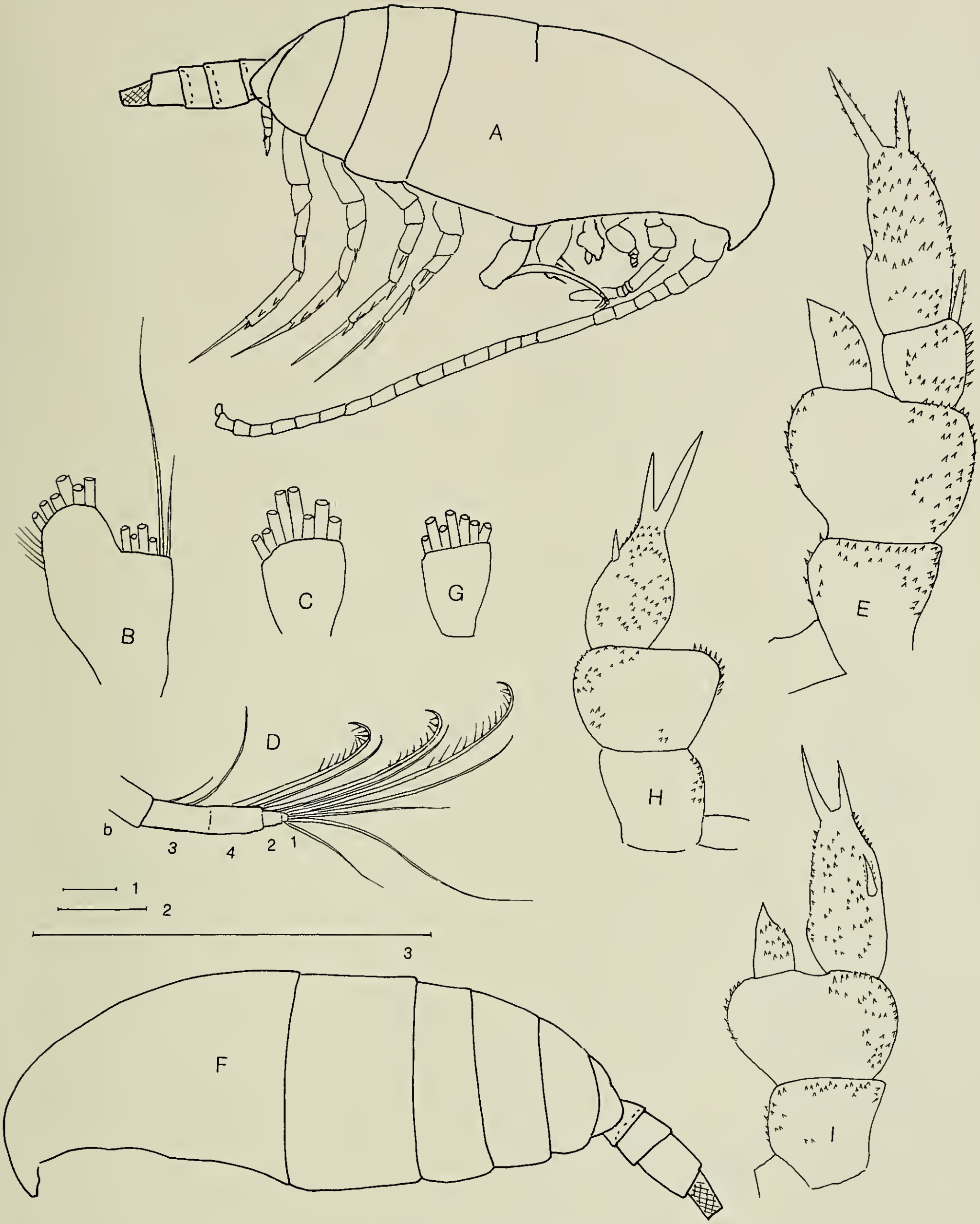

Fig. 5. *Parkius karenwishnerae,* new genus and species, CV male: A, animal, right lateral (CR cross-hatched); B, A2, Ri2; C, Mn, Ri2; D, Mxp, Ri (b = distal tip of basis; numbers below indicate relative appearence of ramal segments during development); E, P5. CIV female: F, animal, left lateral (CR cross-hatched); G, Mn Ri2; H, P5. CIV male: I, P5. Line 1 = 0.1 mm (A); line 2 = 0.1 mm (F); line 3 = 0.1 mm (B–E, G–I).

with 3, 2 + 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 1, 2, 2, 2, 4 + 1 setae + aesthetascs.

A2 (Fig. 8G): Ri terminal segment with 9 (5 terminal, 4 subterminal) setae.

Mn (Fig. 8H): Ri2 with 5 setae.

Mx1 (Fig. 7I): Le with 6 setae. Li 2 with 3 setae. Li1 with 7 apical setae.

Mxp (Fig. 8I, J): syncoxa with 7 setae

Fig. 6. *Parkius karenwishnerae,* new genus and species, CIV female: A, schematic of A1, free segments 1–10; B, A1, free segments 11–18 (# indicate setae which are present only on right A1 of CIV male); C, P1, Re, anterior; D, P2, Re, posterior; E, P3, Re and Ri, posterior; F, P4, Re and Ri, posterior (numbers to right of Re and left of Ri indicate relative appearence of ramal segments during development). Line 1 = 0.1 mm (A, B); line 2 = 0.1 mm (C, E, F); line 3 = 0.1 mm (D).

Fig. 7. *Parkius karenwishnerae,* new genus and species, CIII: A, animal, right lateral (CR cross-hatched); B, A1, free segments 1–14; C, A1, free segments 15–19; D, free segments 20–23; E, Mx1, posterior; F, P5 (tip of arrow) near posterior edge of Th6 and Th7 (#). CII: G, A1, free segments 1–12; H, A1, free segments 13–19; I, Mx1, posterior; J, P4 at posterior edge of Th5 (Th6 with #). Wavy line cutoff indicates broken setae. Line 1 = 0.1 mm (A); line 2 = 0.1 mm (B–D, G, H); line 3 = 0.1 mm (E, F, I, J).

Fig. 8. *Parkius karenwishnerae,* new genus and species, CIII: A, A2, Ri2; B, Mn, Ri2; C, Mxp, Ri (b = distal tip of basis; numbers to left indicate relative appearence of ramal segments during development); D, P3, Re, posterior; E, P4, posterior (numbers to right of Re and left of Ri indicate relative appearence of ramal segments during development). CII: F, animal, left lateral (CR cross-hatched); G, A2, Ri2; H, Mn, Ri2; I, Mxp, syncoxa; J, Mxp, Ri (b = distal tip of basis; numbers to left indicate relative appearence of ramal segments during development); K, P2, Re, posterior; L, P3, posterior. Wavy line cutoff indicates broken setae. Line 1 = 0.1 mm (F); line 2 = 0.1 mm (D, E, I, K, L); line 3 = 0.1 mm (A–D, H, J).

(only 2 in disto-medial set); Ri 3-segmented with 4, 0, 0 setae.

P2 (Fig. 8K): Re 2-segmented with 7 (4 medial, 1 terminal, 2 lateral), 1 (lateral) setae.

P3 (Fig. 8L): coxa unarmed. Re 1-segmented with 7 (3 medial, 1 terminal, 3 lateral) setae. Ri 1-segmented with 6 (3 medial, 2 terminal, 1 lateral) setae.

P4 (Fig. 7J): a bilobe bud on posterior edge of Th5; dorsal lobe with 3 weakly-sclerotized setae, ventral lobe with 2 weakly-sclerotized setae; lobes and setae directed dorsally.

Etymology.—This new species honors Dr. Karen Wishner for her many and varied contributions to the biology of the oceans.

Remarks.—Adult females of *P. karenwishnerae* share with species of the calanoid superfamilies Ryocalanoidea, Spinocalanoidea, and Clausocalanoidea, a 1-segmented endopod on leg 1, and a 2-segmented endopod on leg 2. Adult males of species of the latter two superfamilies have non-geniculate antenna 1, a character state we have been unable to determine for the new species. Adult females of *P. karenwishnerae* share with species of the Clausocalanoidea three inner setae on the first exopodal segment of leg 1 and four inner setae on the first exopodal segment of leg 2 (Park 1986). Adult females of *Parkius* share: with diaixids, tharybids, phaennids and scolecitrichids, Bradford's setae on the sixth enditic lobe on the basis plus exopod of maxilla 2; with diaixids and scolecitrichids three apical Bradford's setae without setules and five more with apical setules on this segment complex; with diaixids, phaennids and scolecitrichids distally and/or radially polarized denticles on the posterior surfaces of some ramal segments of legs 2–4; with most scolecitrichids two Bradford's setae on the fifth enditic lobe on the basis of maxilla 2. The combination of the following derived character states separates Parkiidae from the other bradfordian families: maxilla 2 with two Bradford's setae on the fifth enditic lobe on the basis; maxilliped with two medial setae on the basis; and 4, 0, 1, 1, 1 setae on its endopodal segments (reduced by truncation during development); and one leg 1 anterior denticles of Von Vaupel Klein's organ proximal to the presumptive boundary of the second endopodal segment.

The shapes of maxillipedal segments are diagnostic for *Parkius*; an elongate basis distal to the medial row of denticles and distal to the two medial setae; endopodal segments 2–5 of the maxilliped attenuate, forming a hook-like structure distally, with denticles along the concave margin.

Neither homologies of Bradford's setae at various positions on maxilla 2, nor the transformation sequence of those setae have been hypothesized. We do not know the ancestral state for numbers of Bradford's setae on the sixth enditic lobe of the basis plus exopod of maxilla 2 although presence of one sclerotized seta on *Tharybis macrophthalma* may be a primitive condition. We believe that the presence of four sclerotized setae on the fifth enditic lobe on the basis is primitive, and that two Bradford's setae on that lobe is a derived character state. Phylogenetic hypotheses about species within bradfordian families await careful collecting, better preservation and complete descriptions of appendage armament. Of particular value to our understanding of relationships among the species are the armament of maxilla 1, presence of Bradford's setae on the fifth and sixth enditic lobes and exopod of maxilla 2, shape and armament of maxilla 2, armament of the maxilliped, structure of Von Vaupel Klein's organ, presence of radially polarized denticles on legs 2–4, homologies of segments and setae of leg 5.

Segmental and setal homologies.—The number of segments and associated setae on the ramus of maxilla 2 of the ancestor to the bradfordian families is difficult to infer based on our present knowledge of clausocalanoideans. Presumed older calanoids like *Pleuromamma xiphias* or *Ridgewayia klausruetzleri* with two enditic lobes on the basis (the fifth and sixth enditic lobes) have seven exopodal setae (Ferrari 1985, Ferrari 1995). Presence of eight setae on the distal segments of many species in the bradfordian families apparently is correlated with reduction in size of the sixth enditic lobe. The hypothesis accepted here is that the sixth lobe, apparently with at least one of its setae, are included in the exopod and group of eight Bradford's setae, although the homologies of each of these setae cannot as yet be determined. The tip of maxilla 2 then is a complex of exopodal segments plus the sixth enditic lobe on the basis whose setation is complete early in the copepodid phase of calanoid development. This hypothesis is supported by the fact that, in general, setation of enditic lobes and exopodal segments are complete early in calanoid copepodid development (Ferrari 1995).

A medial row of denticles is found on the proximal portion of the basis of the maxilliped of many copepods. Usually this row ends at the level of the second of three medial setae. On *P. karenwishnerae* these denticles and only two medial setae, occupy the proximal one-fourth of the basis; the distal portion of the basis is elongate. Some species of the phaennid genus *Onchocalanus* have a maxilliped with an elongate basis (Park 1983). However, in *O. trigoniceps, O. paratrigoniceps, O. magnus,* and *O. cristatus* the area of elongation is not homologous to *P. karenwishnerae* because it apparently results from the proliferation of cells immediately distal to the medial denticle row so that cells producing the three medial setae of the basis are included in the area of elongation. In *Parkius karenwishnerae* this area of elongation apparently results from the proliferation of cells distal to the two medial setae as well as the medial denticle row, so that cells producing the two medial setae are not included in the area of elongation.

Table 2 compares setation during copepodid development of the maxilliped of *P. karenwishnerae,* the related scolecitrichid

Table 2.—Setation of the maxilliped of *Parkius karenwishnerae* and *Scopalatum vorax* for stages CII–CVI and of *Ridgewayia klausruetzleri* for stages CI–CVI. Beginning with CII, setation of the endopod of the scolecitrichid, *S. vorax*, is identical to the presumed older calanoid, *R. klausruetzleri. P. karenwishnerae* exhibits delayed appearance of the fifth endopodal segment, no seta at the formation of endopodal segments 2–4, and truncation of post-formation setal addition on three endopodal segments. Lobes of the syncoxa (s1–s4), the basis (b) and its distomedial lobe (l), and the endopodal segments (*n1–n5* numbered by developmental stage) are arranged from left, proximally, to right, distally. a = segment not formed.

	s1	s2	s3	s4	b	l	*n3*	*n4*	*n5*	*n2*	*n1*
Parkius karenwishnerae											
CI	?	?	?	?	?	?	?	?	?	?	?
CII	1	2	2	3	2	1	*0*	*a*	*a*	*0*	*4*
CIII	1	2	2	3	2	1	*0*	*0*	*a*	*0*	*4*
CIV	1	2	2	3	2	2	*1*	*1*	*a*	*0*	*4*
CV	1	2	2	3	2	2	*1*	*1*	*a*	*0*	*4*
CVI	1	2	2	3	2	2	*1*	*1*	*1*	*0*	*4*
Scopalatum vorax	s1	s2	s3	s4	b	l	*n3*	*n4*	*n5*	*n2*	*n1*
CI	?	?	?	?	?	?	?	?	?	?	?
CII	1	2	1	3	2	2	*1*	*a*	*a*	*1*	*4*
CIII	1	2	1	3	3	2	*1*	*1*	*a*	*2*	*4*
CIV	1	2	1	3	3	2	*2*	*2*	*1*	*2*	*4*
CV	1	2	1	3	3	2	*3*	*3*	*2*	*3*	*4*
CVI	1	2	1	3	3	2	*4*	*4*	*3*	*4*	*4*
Ridgewayia klausruetzleri	s1	s2	s3	s4	b	l	*n3*	*n4*	*n5*	*n2*	*n1*
CI	0	1	2	2	2	1	*a*	*a*	*a*	*1*	*4*
CII	1	2	4	3	3	2	*1*	*a*	*a*	*1*	*4*
CIII	1	2	4	3	3	2	*1*	*1*	*a*	*2*	*4*
CIV	1	2	4	3	3	2	*2*	*2*	*1*	*2*	*4*
CV	1	2	4	3	3	2	*3*	*3*	*2*	*3*	*4*
CVI	1	2	4	3	3	2	*4*	*4*	*3*	*4*	*4*

Scopalatum vorax, and *R. klausruetzleri,* a presumed older calanoid. Ferrari & Steinberg (1993) incorrectly figured and described *S. vorax* with three setae on the proximal (third) endopodal segment at CIV; the correct number for that stage is two. There are no differences between *S. vorax* and *R. klausruetzleri* in segmentation or setation of the endopod. However, *S. vorax* has three fewer setae on a lobe of the syncoxa and the addition to the basis of the third medial seta is delayed until CIII. *Parkius karenwishnerae* has two fewer setae on the homologous syncoxal lobe, a third medial seta is never added to the basis, the addition of the second seta to the disto-medial lobe of the basis is delayed until CIV, and the addition of the fifth endopodal segment is delayed until CVI. These changes are neotenic because appearances of segments or setae are delayed until late in development or delayed so that they do not appear at all. There is no seta present at the formation of endopodal segments 2–4 of *P. karenwishnerae,* and only one of three plus three post-formation setae are added to endopodal segments 3 and 4. The pattern of endopodal setation exhibited by *R. klausruetzleri* and *S. vorax* appears to have been truncated in *P. karenwishnerae,* resulting in a reduction in setal number on the endopod. An alternate hypothesis of neotenic reduction, i.e., delaying setal addition, is not supported by the pattern for *P. karenwishnerae* because final setal numbers are reached at CIV rather than CVI. Thus two developmental processes, neoteny and truncation, may be responsible for setal addition to the maxilliped of *P. karenwishnerae.*

The morphology of Von Vaupel Klein's organ suggests that the 1-segmented endopod of leg 1 of *P. karenwishnerae* is a segment complex. The development of leg 1 of *P. karenwishnerae* is incompletely reported here, but we assume that its morphology at CI is similar to *Drepanopus forcipatus* with 1-segmented exopod and endopod (Hulsemann 1991), and without presumptive structures of Von Vaupel Klein's organ (also see Ferrari, 1995, for development of *R. klausruetzleri*). On *D. forcipatus, S. vorax* or *P. karenwishnerae* this endopod does not add segments or setae later in development; however, structural elements of Von Vaupel Klein's organ (tubercle and curved basal seta) presumabley are added during the molt to CII. At this stage in development of presumed older calanoids like *R. klausruetzleri,* which continue to add segments and setae to leg 1 endopod during development, the endopod is 2-segmented. For CII of *R. klausruetzleri* the boundary between the second (proximal) and first (distal) endopodal segments of a 2-segmented endopod has formed between the 2 medial setae of the endopod of CI, and the tubercule of Von Vaupel Klein's organ is located near that boundary. Later in development the tubercule is located near the boundary of the second (proximal) and third (middle) endopodal segments of the 3-segmented endopod at CV of *R. klausruetzleri* and *P. xiphias.* Based on the position between the two proximal inner setae of this presumed homologous denticule bearing tubercule, we believe that the 1-segmented endopod of leg 1 of *D. forcipatus,* species of *Euchirella* and *Pseudochirella* mentioned by Von Vaupel Klein (1972), and *S. vorax* is a complex of cells of the first and second endopodal segments which are not separated by an arthrodial membrane. The 1-segmented ramus of *P. karenwishnerae* also is a segment complex, but without a distinct tubercle. The homologous denticles are located away from the boundary of the presumed second and first segments. The alternate hypothesis, that the 1-segmented endopod of leg 1 is simply the first endopodal segment of CI, would require Von Vaupel Klein's organ to have evolved independently among calanoids with 1-segmented and with 2- or 3-segmented endopods on leg 1.

The pattern of development of legs 1–4 of *P. karenwishnerae* is identical to *S. vorax* although Ferrari & Steinberg (1993) incorrectly described the second exopodal segments of leg 4 of CIV male and of leg 3 of CIII with two setae (they have one seta), and the endopod of leg 4 which at CIII was incorrectly described and illustrated with five setae (there are six; the proximal, medial one was not shown). The ramus on female leg 5 appears to be an exopod, because it is morphologically similar to the outer ramus of the male. Distal structures on the exopod of female leg 5 exopod of *P. karenwishnerae* and both rami of the male do not articulate with the segment but instead appear to be attenuations of the segment.

Bradford (1973) and Bradford et al. (1983) have made significant contributions to our understanding of the specialized clausocalanoidean families Phaennidae and Scolecitrichidae despite the fact that the morphology of many described species is incompletely known. Most of the species live in deep water and thus few specimens have been available for study; adult males are usually rare. In addition, the ramal segments of legs 1–4 are often broken during capture, and Bradford's setae, which are weakly-sclerotized, may become distorted over time in ethanol, a commonly used preservative. A better understanding of relationships among bradfordian families has been hampered by incomplete descriptions of species in the families Diaixidae and Tharybidae. Here maxilla 1, maxilla 2, maxilliped and endopod of leg 1 are redescribed for *Diaixis hibernica* (Scott 1896) and *Tharybis macrophthalma* Sars 1902, which are the type species of the type genera of their respective families.

Diaixidae Sars, 1902
Diaixis Sars, 1902
Diaixis hibernica (Scott 1896)

Material examined.—CVI 5 females and 2 males plus several other copepodids from Raunefjord, Norway (60°16′N, 5°10′E) collected by Audun Fosshagen on 4 April 1995 with a Beyer epibenthic sampler (180 micron mesh) at 120 m have been deposited in the U.S. National Museum (USNM 278204).

CVI female.—Mx1 (Fig. 9A) Le with 8 setae. Re 1-segmented with 8 setae; baseoendopod with sets of 3, 3, 3, and 3 setae. Li2 with 2 setae, Li3 with 3. Li 1 with 8 apical setae.

Mx2 (Fig. 9B, C): Li 1–4 on coxa each with 4, 3, 3, 3 setae each; li5 on basis with 4 setae, 1 weakly-sclerotized without setules. Li2 + Re an indistinctly segmented complex with 8 Bradford's setae; terminal 3 thick without setules, 5 thinner with apical setules.

Mxp (Fig. 9D–E): syncoxa with denticles on disto-medial margin and 9 setae (1 Bradford's with setules along its length and 2 Bradford's with narrow base and without apical setules). Basis with medial row of denticles and 3 medial setae; disto-medial lobe with 2 setae. Ri 5-segmented with 4, 4, 4, 4, 3 setae.

P1 (Fig. 9F, G): Von Vaupel Klein's organ with an area of long, thin denticles laterally on anterior face of Ri. There are also 3 areas on denticles on the posterior face of Ri.

CVI male.—Differs from CVI female as follows. Mx1 (Fig. 10A) Le with 4 setae. Re 1-segmented with 7 setae; Ri with 1 medial and 4 apical setae. Li1–3 unarmed.

Mx2 (Fig. 10B): Li 1–3 on coxa with numerous small denticles; li 4 with a sclerotized seta and denticles; li5 on basis with 1 Bradford's seta without setules. Li2 with 1 Bradford's seta with setules; Re indistinctly segmented with 5 Bradford's setae; terminal 3 thick without setules, and 2 shorter with apical setules.

Mxp (Fig. 10C): syncoxa with 4 setae (1 Bradford's with apical setules). Basis with medial row of denticles and 2 medial setae.

Remarks.—We examined from The Natural History Museum in London one lot (B.M. 1911.11.8 37900–907) of *Scolecithrix hibernica* labelled types by A. Scott and "Feby 1896" from the Irish Sea which contained CVI 4 females, 5 males; CV 1 female, 2 males, and one lot from the Zoological Museum of the University of Oslo (F 20677) labeled "*Diaixis hibernica* A. Scott, sted. Bundefj., dt. G. O. Sars" which contained CVI 12 females, 1 male; CV 5 females, 2 males. We did not dissect specimens from either lot, but adult females from both lots agree with Raunefjord specimens in morphology of the posterior margin of the prosome and of the genital complex; we believe all specimens are conspecific. For adult females of both lots, we were able to verify the general shape of

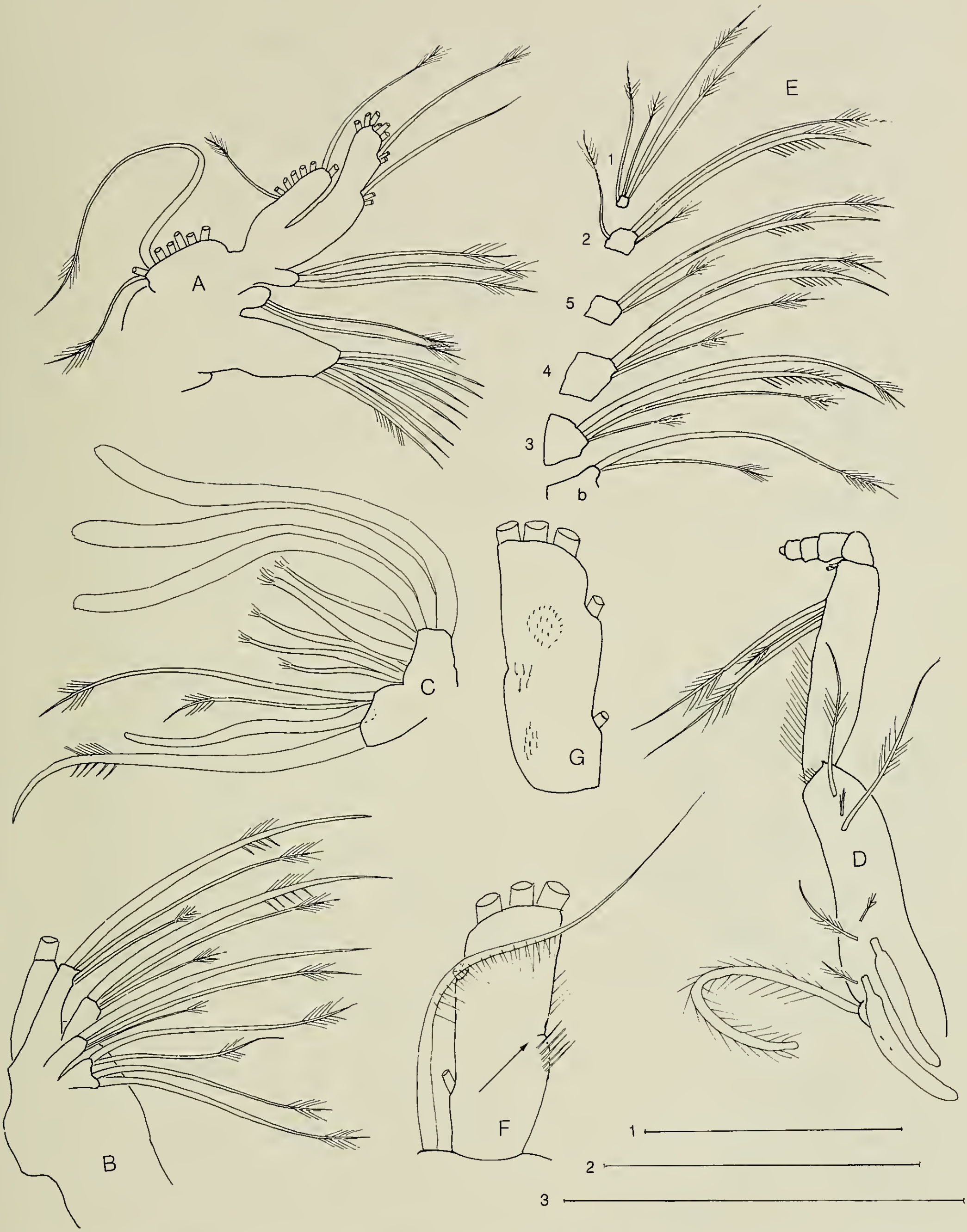

Fig. 9. *Diaixis hibernica* (Scott, 1896), female: A, Mx1, posterior; B, Mx2, li1–4 on syncoxa, posterior (li5 with one seta with circular cutoff also shown); C, Mx2, li5 on basis and li6 + Re, anterior; D, Mxp (setation of Ri not shown); E, Mxp, Ri (b = distal tip of basis; numbers to left indicate relative appearence of ramal segments during development); F, P1, Ri, anterior (arrow indicates approximate position of presumptive boundary between Ri1 and Ri2, between proximal two medial setae); G, P1, Ri, posterior. Line 1 = 0.1 mm (A–D); line 2 = 0.1 mm (E); line 3 = 0.1 mm (F, G).

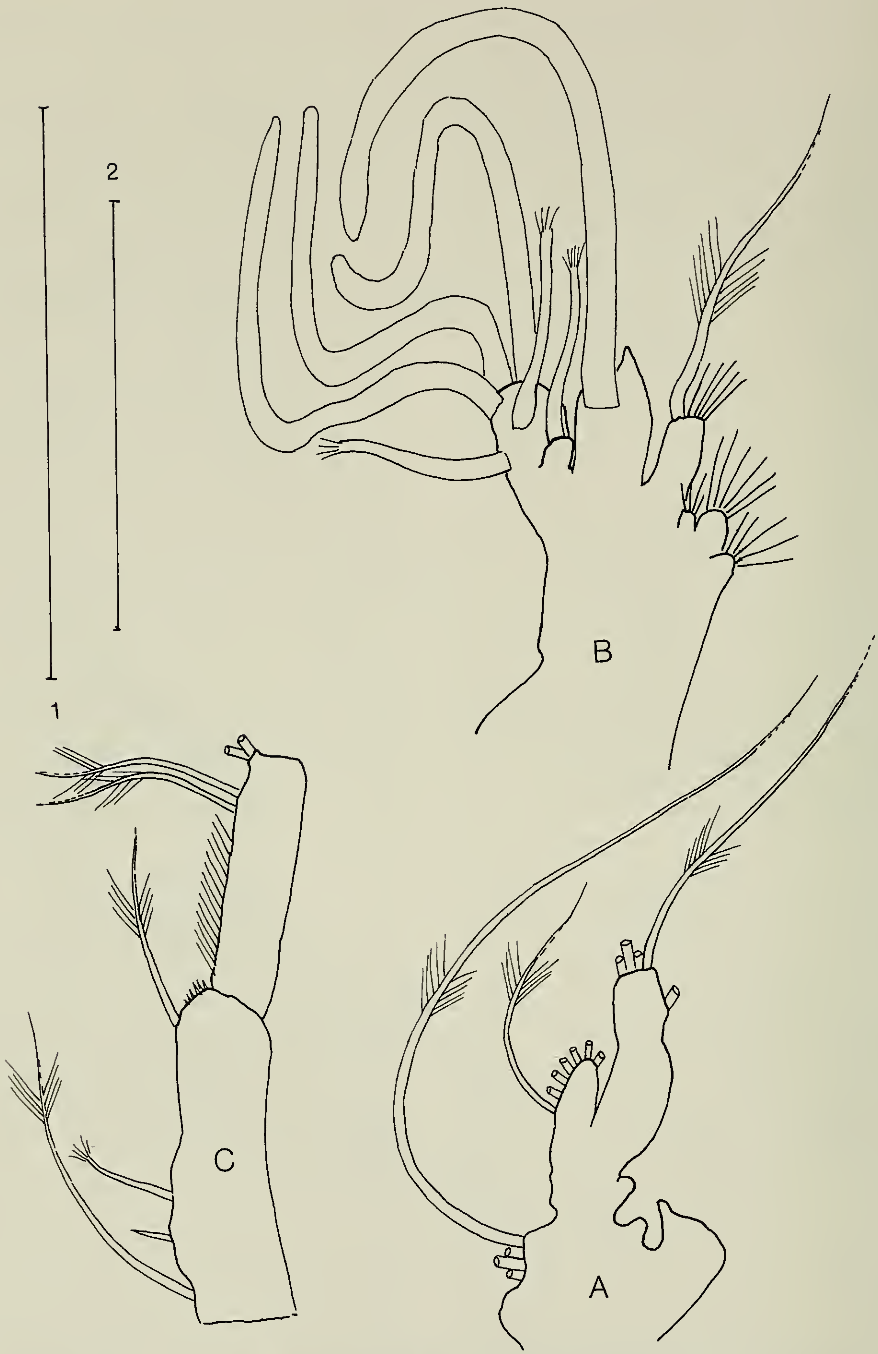

Fig. 10. *Diaixis hibernica* (Scott, 1896), male: A, Mx1, posterior; B, Mx2; C, Mxp, coxa and basis. Line 1 = 0.1 mm (A, B); line 2 = 0.1 mm (C).

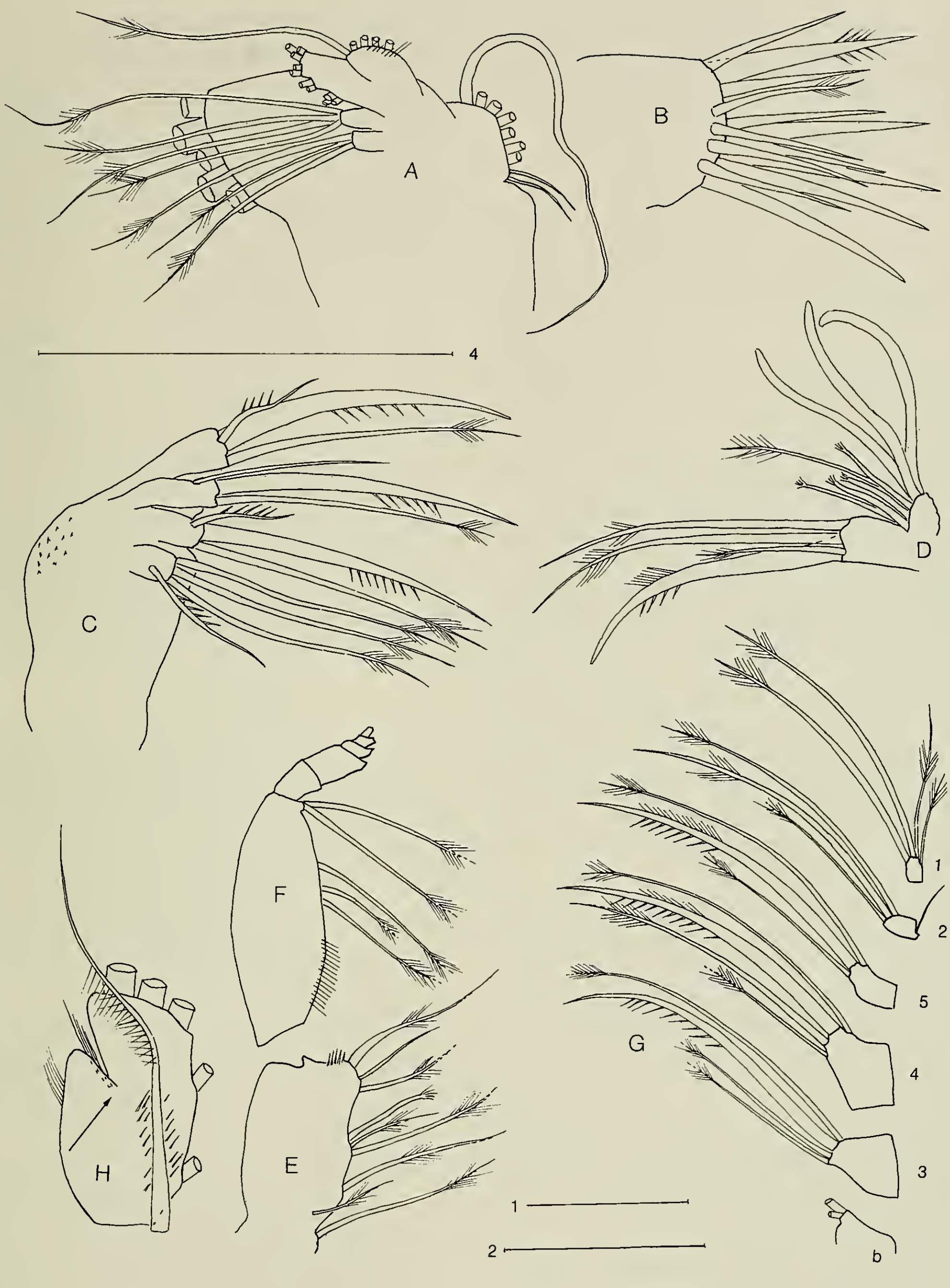

Fig. 11. *Tharybis macrophthalma* Sars, 1902: A, Mx1, anterior; B, Mx1, tip of li1, posterior; C, Mx2, li1–4 on syncoxa, posterior; D, Mx2, li5 on basis and li6 + Re, anterior; E, Mxp, syncoxa; F, basis and Ri (setation of Ri not shown); G, Mxp, Ri (b = distal tip of basis; numbers to right indicate relative appearence of ramal segments during development); H. P1, Ri, anterior (arrow indicates approximate position of presumptive boundary between Ri1 and Ri2, between proximal two medial setae). Line 1 = 0.1 mm (E, F); line 2 = 0.1 mm (A, B); line 3 = 0.1 mm (C, D, G); line 4 = 0.1 mm (H).

Mx1 and setation of the exite, the armament of li6 plus Re of Mx2, and setation of basis and presence of 19 setae on Ri of Mxp which agree with Raunefjord specimens.

Tharybidae Sars, 1902
Tharybis Sars, 1902
Tharybis macrophthalma Sars, 1902

Material examined.—CVI 9 females and 10 males from Raunefjord, Norway (60°16′N, 5°10′E) collected by Audun Fosshagen on 4 April 1995 with a Beyer epibenthic sampler (180 micron mesh) at 120 m have been deposited in the U.S. National Museum (USNM 278205).

CVI female.—Mx1 (Fig. 11A, B): Le with 9 setae. Re 1-segmented with 5 setae; baseoendopod with sets of 3, 2, 2, and 3 setae. Li 2 with 3 setae, Li3 with 4. Li 1 with 9 apical (5 thick with setules, 4 thin and unarmed) and 4 posterior setae.

Mx2 (Fig. 11C, D): Li 1–4 of coxa each with 4, 3, 3, 3 setae each; li5 on basis with 4 sclerotized setae. Li2 + Re an indistinctly segmented complex with 8 setae; terminal 3 Bradford's setae without setules, 4 Bradford's setae with apical setules, and 1 sclerotized seta with setules.

Mxp (Fig. 11E–G): syncoxa with denticles on disto-medial margin and 9 setae (1 short Bradford's with apical setules). Basis elongate with medial row of denticles followed by 3 setae; disto-medial lobe with 2 setae. Ri 5-segmented with 4, 4, 4, 4, 3 setae.

P1 (Fig. 11H): Von Vaupel Klein's organ with lateral margin of Ri extended distally; denticles medial and lateral to the extension, and on the anterior face of Ri below the basal seta.

CVI male.—Mx1, Mx2, Mxp, and P1 similar to female.

Remarks.—We examined one lot from the Zoological Museum of the University of Oslo (F 20610) labeled "*Tharybis macrophthalma* G. O. Sars, sted. Drobak, dt. G. O. Sars" which contained CVI 5 females, 2 males; CV 1 male. We did not dissect these specimens but adult females agree with Raunefjord specimens in morphology of leg 5 and the genital complex; we believe specimens from both areas are conspecific. For adult females we were able to verify the armament of li6 plus Re of Mx2, and setation of coxa and basis, and the presence of 19 setae on Ri of Mxp.

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